APPROXIMATING AN INDUSTRY-SPECIFIC GLOBAL ECONOMIC MODEL OF TRADE POLICY

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Abstract

It is preferable to analyze the economic effects of tariff changes using global economic models that include every country and explicitly take into account trade diversion. However, the data requirements of global models can be difficult to meet, even when modeling international trade within a narrowly defined industry. It is common practice to use simpler single market models with import supply elasticity values that represent international trade links in an abbreviated way and only implicitly account for trade diversion, but it is challenging to determine the appropriate supply elasticity values to use as model inputs. In this paper, we derive import and domestic supply elasticity values for single market models that are consistent with a more fully specified global model of tariff changes. We identify the factors that should be reflected in these supply elasticity values, including the importing country's share of the exporter's global market, the extent of substitution between varieties from different countries, and the flexibility of industry production in each country. We apply the model in a series of simulations of changes in tariffs on U.S. imports of manufacturing products.

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1 Introduction

Tariffs on imports can have significant economic effects on an economy, altering trade flows, market prices, production levels, and employment. Economic models can be used to quantify these effects. It is preferable to analyze the effects of tariff changes using global models that explicitly accounts for trade diversion; however, the data requirements of global models can be difficult to meet, even when modeling international trade within a narrowly defined industry.

It is common practice to use simpler single market models with import supply elasticity values that represent international trade links in an abbreviated way and only implicitly account for trade diversion.[1] The import-competing domestic industry is still linked to the rest of the world, but these links are not modeled explicitly. Instead they are represented by response functions, called import supply curves, with constant price elasticity parameters. The elasticity values are often based on ad hoc guesses, or possibly on estimates from the econometrics literature that might not be the best fit for the specific industry and time period that are the focus of the model.

There are many advantages of using single market models to analyze industry-specific changes in trade policy. They can be practical and convenient, with lower data requirements than industry-specific global models and *much* lower data requirements than global computable general equilibrium models. In addition, they can be flexibly tailored to capture distinctive structural features of the modeled industry, like its pattern of market concentration or the role of foreign direct investment.[2] Still, it is challenging to determine the appropriate supply elasticity values to use as model inputs.

In this paper, we develop a method for calibrating the domestic and import supply

[1] Riker and Schreiber (2020) provides a large number of partial equilibrium models for analyzing changes in trade policies.

[2] For example, these issues are incorporated into partial equilibrium models in Riker (2018), Riker (2019), and Riker and Schreiber (2019).

elasticity values for a single market model using the estimated effects from a fully specified global model with linked national markets. The supply elasticity values should reflect both the flexibility of production in each country and the potential to divert shipments to different national markets. They should reflect the importing country's share of the exporter's global market and the extent of substitution between varieties from different countries.

We introduce the single market model of tariff changes in Section 2, and then we derive a global model of the same industry with linked national markets in Section 3. We show that there is a unique set of supply elasticity values for the single market model that replicates the quantity and price effects implied by the global model, and these elasticity values can be used to calibrate the single market model when simulating the effects of a range of different tariff changes.

We apply this two-part approach in Section 4. We calibrate a global model to data on domestic and import shipments of electrical equipment in 2014, and then we run simulations of the effects of a hypothetical tariff increase on U.S. imports of electrical equipment from China on the prices facing U.S. consumers and the quantities of domestic shipments and U.S. imports. We also use the global model to calculate supply elasticity values for a U.S.-focused single market model. Then we reapply the method to eleven other manufacturing industries in Section 5. These additional simulations illustrate that the approximate supply elasticity values can be single-digit, double-digit, or triple-digit positive numbers and even negative numbers.

Our approach to calibrating the supply elasticity values makes several contributions to industry-specific modeling of tariff changes. First, we provide a set of estimated supply elasticity values that can be adjusted, using a global structural model, to industry-specific data on global shipment shares if these data are available. Even for industries for which data are more limited, the global model provides guidance for what economic factors can be used to *approximate* the elasticity values for a single market model of an industry. We conclude with a summary of findings in Section 6.

2 Single Market Equilibrium Model of Tariff Changes

First, we introduce the single market model. The partial equilibrium framework focuses on a specific industry in isolation, assuming that the industry is small enough relative to the rest of the national economy that aggregate expenditures and factors prices are not significantly affected by industry-specific tariff changes. The model focuses on domestic shipments and imports into one national market, country k.

Consumers have nested CES preferences, with an elasticity of substitution equal to one between industries and equal to σ between products from different countries within the industry. Equation (1) represents the demand curves in market k.

$$q_{jk} = b_{jk}\ E_k\ \left(I_k\right)^{\sigma-1}\ \left(p_{jk}\ \tau_{jk}\right)^{-\sigma} \tag{1}$$

q_{jk} is the quantity of the product from source country j demanded in country k, b_{jk} is a demand shift parameter specific to industry products from country j, E_k is aggregate expenditures in country k, I_k is the industry's price index in country k, p_j is the producer price in country j for exports to country k, and $\tau_{jk} > 1$ is the trade cost factor for products sent from country j to country k. When $j \neq k$, q_{jk} is the quantity of imports. When $j = k$, q_{jk} is the quantity of domestic shipments.

Equation (2) represents the supply curves of the model.

$$q_{jk} = a_j\ \left(p_{jk}\right)^{\theta_{jk}} \tag{2}$$

θ_{jk} is the price elasticity of supply from country j to country k, and a_j is a supply parameter for the industry's production in country j.

Equations (3), (4), and (5) rewrite these equilibrium conditions in log-linearized form, as percent changes in the endogenous variables ($\hat{q}_{jk}$, $\hat{p}_{jk}$, and $\hat{I}_k$) resulting from exogenous percent changes in the trade cost factor ($\hat{\tau}_{jk}$), holding all of the other exogenous variables (b_{jk}, a_j, and E_k) constant.

$$\hat{q}_{jk} = (\sigma - 1)\ \hat{I}_k - \sigma\,(\hat{p}_{jk}\ +\ \hat{\tau}_{jk}) \tag{3}$$

$$\hat{I}_k = \sum_j\ X_{jk}\ \ (\hat{p}_{jk}\ +\ \hat{\tau}_{jk}) \tag{4}$$

$$\hat{q}_{jk} = \theta_{jk}\ \hat{p}_{jk} \tag{5}$$

X_{jk} is the share of total industry expenditure in country k on products that originate in country j. In equilibrium, the percent reduction in the quantity shipped from country j to country k, $\hat{q}_{jk}$, will be magnified when θ_{jk} is larger. These supply elasticity values are important inputs of the single market model, so we develop a methodology for quantifying these values.

In the next section, we show that there is an underlying global model that can be abbreviated by the single market model in (3), (4), and (5). By specifying the more complete global model, we are able to identify the factors that determine the appropriate supply elasticity values for the single market model and, with adequate data, we are able to calibrate these values exactly. We show that there is a unique set of supply elasticity values for the single market model that replicates the quantity and price effects in each global model simulation.

3 Global Equilibrium Model

The global model is more complex and complete, with several countries that produce and consume the products of the industry and with product differentiation by source country. We assume that the industry in country j has a Cobb-Douglas production function with a cost share β_j for variable factors of production and a cost share $(1 - \beta_j)$ for industry-specific factors that are fixed in supply, at least in the short run. There is diminishing returns to adding variable factors of production, since $\beta_j < 1$, and this results in an upward-sloping short run cost curve for industry production in country j.

The demand curves and price indices in (3) and (4) still apply. However, the global model replaces the supply curves represented by (5) with supply equations represented in (6).

$$\sum_k Y_{jk} \hat{q}_{jk} = \left(\frac{\beta_j}{1 - \beta_j}\right) \hat{p}_{jk} \tag{6}$$

Y_{jk} is the share of the total shipments of country j that are sent to country k. Y_{kk} is the domestic shipment share. If there are N countries, then the model has N equations with the form in (6). Each of these equations sets the global demand for the product from one of the source countries equal to its production.

Before calibrating the global model to industry data, we analyze the comparative statics of the model to illustrate how the industry's international shipment shares shape the estimated price and quantity effects of a tariff change. To keep the illustration simple, we assume that there are only two countries in the global market of the specific industry, j and k, and that the only policy change is an increase in the tariff rate on country k imports from country j, starting from an equilibrium with no tariffs. We use (3), (4), and (6) to solve for the price and quantity effects ($\hat{q}_{jk}$, $\hat{q}_{kk}$, $\hat{p}_{jk}$, and $\hat{p}_{kk}$) resulting from the tariff increase ($\hat{\tau}_{jk}$). Then we calculate the ratios of these percent changes, $R_{j,k} = \frac{\hat{q}_{jk}}{\hat{p}_{jk}}$ and $R_{k,k} = \frac{\hat{q}_{kk}}{\hat{p}_{kk}}$. Finally, we take the derivative of these ratios with respect to the parameters of the global model.

The ratio for imports from j to k, $R_{j,k}$, is declining in the importing country's share of global consumption of the products of the industry. The ratio is higher for an importing country that is small relative to the global market of the specific industry. On the other hand, the ratio is increasing in the importing country's share of global production, the elasticity of substitution, and the price elasticity of production in each country. These factors jointly determine the extent of trade diversion and the price responsiveness of production.

The ratio of domestic shipments in country k, $R_{k,k}$, is declining in the importing country's share of global consumption of the products of the industry. It is larger for countries with only small shares of global production in the industry. The ratio is also declining in the price elasticity of production in each country, increasing in the elasticity of substitution, and invariant to the importing country's share of global production.

4 Application to U.S. Imports of Electrical Equipment

Next we calibrate the global model to a specific industry, electrical equipment, and simulate the effects of a hypothetical tariff increase on U.S. imports from China. For this application of the model, we aggregate the world into five country-regions: the United States (us), China (ch), Japan and Korea (jk), the European Union (eu), and an aggregate of the rest of the world (rw). We use bilateral trade values between these country-regions for the electrical equipment industry in 2014 from WIOD.[3] We use an estimate of the elasticity of substitution for the industry that is reported in Hertel, Hummels, Ivanic and Keeney (2007). We set β_j in all of the country-regions equal to the specific industry's cost share of production workers and materials in the 2017 Economic Census of the United States.

[3]Many prominent recent studies use WIOD data to calibrate models of international trade. Examples include Costinot and Rodríguez-Claire (2014), Fajgelbaum and Khandelwal (2016), and Adao, Costinot and Donaldson (2017).

4.1 Simulations Using a Global Model

Table 1 reports the value of domestic shipments and international trade in electrical equipment between the country-regions in millions of U.S. dollars.

Table 1: Domestic and International Shipments of Electrical Equipment

Source Country	To the United States	To China	To Japan and Korea	To the European Union	To the Rest of the World
United States	93,694	1,840	1,737	3,912	24,412
China	32,069	834,892	31,143	39,429	118,472
Japan and Korea	9,750	23,971	135,392	8,855	38,335
European Union	10,983	16,776	6,355	250,555	69,629
Rest of World	33,978	17,938	10,162	23,971	531,999

Table 2 reports the estimated price and quantity effects from a set of global model simulations that all set $\sigma = 8.1$, $\beta = 0.593$, and $\hat{\tau}_{ch,us} = 0.0454545$ (a hypothetical 5% tariff on U.S. imports from China).

Table 2: Simulations Using the Global Model

Estimates	Separate Supply for Domestic and Export	Common Global Supply	Market-Specific Dedicated Supply
(in % Changes)			
$\hat{p}_{us,us}$	0.97	0.64	0.37
$\hat{p}_{ch,us}$	-0.51	-0.18	-3.48
$\hat{p}_{jk,us}$	0.06	0.03	0.37
$\hat{p}_{eu,us}$	0.02	0.04	0.37
$\hat{p}_{rw,us}$	0.36	0.07	0.37
$\hat{I}_{us}$	1.31	1.15	0.50
$\hat{q}_{us,us}$	1.42	2.96	0.54
$\hat{q}_{ch,us}$	-23.40	-27.16	-5.07
$\hat{q}_{jk,us}$	8.81	7.91	0.54
$\hat{q}_{eu,us}$	9.13	7.87	0.54
$\hat{q}_{rw,us}$	6.40	7.58	0.54
$R_{us,us}$	1.5	4.6	1.5
$R_{ch,us}$	46.3	147.4	1.5
$R_{jk,us}$	139.9	246.2	1.5
$R_{eu,us}$	404.1	212.3	1.5
$R_{rw,us}$	17.8	104.6	1.5

R_{jk} is the ratio of $\hat{q}_{jk}$ to $\hat{p}_{jk}$. If supply is entirely dedicated to the specific national market, then this ratio is the elasticity of a traditional supply curve defined by the upward-sloping short-run marginal cost curve of industry production, holding other prices constant. If supply is not dedicated to the specific national market, however, then this ratio is the slope of a *residual* supply curve, defined as the difference between production and shipments to all other countries. In this case, R_{jk} incorporates the simultaneous changes in all other prices in the global market, and the ratio can be very large and even negative, depending on the international shipment shares in the industry.

Table 2 reports three alternative simulations that adopt different assumptions about the market specificity of the supply chains. In all three alternatives, the prices of the U.S. domestic shipments and non-China imports rise. The producer price of imports from China

($p_{ch,us}$) falls, while their tariff-inclusive delivered price ($p_{ch,us}\ \tau_{ch,us}$) rises. The quantity of imports from China falls, while domestic shipments and imports from the rest of the world rise. The ratios of quantity changes to price changes are all positive. The signs of the changes in prices and quantities and the signs of the ratios are the same across the alternative simulations in Table 2, but the magnitudes of these changes are very different.

The first alternative assumes that each country-region has a separate supply chain for exporting and one for domestic shipments. In this case, there can be trade diversion between export markets but not a shift of supply between the domestic market and foreign markets. This is the benchmark simulation.

The other alternatives vary the assumption about the market specificity of these supply chains. The second alternative assumes that each source country-region has a common supply chain serving both domestic and export markets. In this case, there is shifting of supply across all country-regions to equalize the prices of exports and domestic shipments. The reduction in the quantity of imports from China in this second simulation is larger than the benchmark estimates. The increase in the industry consumer price index in the United States is smaller, and all of the ratios are larger.

The third alternative is at the other extreme: it assumes that each country-region has a separate supply chain completely dedicated to supplying consumers in each of the five country-regions, so there is no potential for trade diversion. The reduction in the quantity of imports from China in this simulation is much smaller than the benchmark estimates. The increase in the industry consumer price index in the United States is smaller, and ratios for imports are much lower than their benchmark values.

4.2 Sensitivity to Parameter Values

Table 3 reports the estimated price and quantity effects from additional model simulations that vary the parameter inputs of the global model. In all of the model runs, we adopt the benchmark assumption that each country-region has a supply chain dedicated to domestic shipments and another dedicated to export markets (the first alternative in Table 2).

Table 3: Additional Sensitivity Analysis

Model Runs	v1	v2	v3	v4
Inputs				
σ	8.1	5.0	8.1	8.1
β	0.593	0.593	0.700	0.593
$\hat{\tau}_{ch,us}$	0.045	0.045	0.045	0.091
Estimates (in % Changes)				
$\hat{p}_{us,us}$	0.97	0.73	0.85	1.95
$\hat{p}_{ch,us}$	-0.51	-0.46	-0.45	-1.01
$\hat{p}_{jk,us}$	0.06	0.05	0.06	0.13
$\hat{p}_{eu,us}$	0.02	0.02	0.03	0.05
$\hat{p}_{rw,us}$	0.36	0.27	0.32	0.72
$\hat{I}_{us}$	1.31	1.18	1.25	2.62
$\hat{q}_{us,us}$	1.42	1.07	1.99	2.84
$\hat{q}_{ch,us}$	-23.40	-15.68	-24.24	-46.80
$\hat{q}_{jk,us}$	8.81	4.47	8.40	17.62
$\hat{q}_{eu,us}$	9.13	4.61	8.66	18.27
$\hat{q}_{rw,us}$	6.40	3.38	6.33	12.81
$R_{us,us}$	1.5	1.5	2.3	1.5
$R_{ch,us}$	46.3	33.9	53.4	46.2
$R_{jk,us}$	139.9	87.5	135.0	139.9
$R_{eu,us}$	404.1	190.1	284.4	404.1
$R_{rw,us}$	17.8	12.5	19.9	17.8

Version 1 repeats the benchmark simulation from Table 2. Version 2 reduces the elasticity of substitution (σ) relative to the benchmark value of 8.1. In this case, the reduction in the quantity of imports from China is smaller than the benchmark estimates. The increase in the industry consumer price index in the United States is smaller, and all of the ratios at the bottom of the table are smaller.

Version 3 increases the cost share of variable factors (β) relative to the benchmark value of

0.593, and this makes production in each source country more sensitive to price changes. In this case, the reduction in the quantity of imports from China is larger than the benchmark. The increase in the industry consumer price index in the United States is smaller. Most of the ratios are larger than the benchmark, though one is smaller.

Finally, Version 4 increases the tariff change ($\hat{\tau}_{ch,us}$) relative to the benchmark value of 0.045. This magnifies the changes in all prices and quantities relative to the benchmark estimates without altering the signs of the effects. Importantly, all of the ratios are the same as the benchmark values. The ratios are invariant to the magnitude of the tariff change.

4.3 Simulations Using the Single Market Model

Now that we have specified the underlying global model, we can see that, in general, the domestic and import supply curves in the single market model represent residual supply curves that depend on the changes in the prices of all of the competing products, not just the single price in (2). The domestic and import supply functions in (2) are generally residual supply curves rather than simple supply curves.

However, the single market model still replicates the economic effects simulated in the global model if the supply elasticity values in (5) are set equal to $R_{j,k}$ for all j and k. The pattern of domestic and international shipments throughout the industry's global market all affect the magnitudes of the quantity and price changes, and their impact is completely encapsulated in the ratios for each supplying country-region. The values of θ_{jk} can be single-digit, double-digit, or triple-digit positive numbers and even negative numbers. As long as the supply elasticity values in the single market model are set equal to the ratios implied by the global model, both models will be mathematically equivalent by construction, and they will generate the same estimated changes in prices and quantities for a specific set of model inputs.

The same supply elasticity values derived from a global model for one specific tariff reduction can be used to simulate the effects of a variety of different tariff reductions, since the R_{jk} ratios are invariant to the magnitude of the tariff changes in the global model, as we demonstrated in the comparative static analysis. Table 4 reports a set of five simulations that all use a single market model and set the supply elasticity values at the benchmark values in Table 2 ($R_{us,us} = 1.457$, $R_{ch,us} = 46.2532$, $R_{jk,us} = 139.879$, $R_{eu,us} = 404.12$, and $R_{rw,us} = 17.8089$, to be exact), with all parameter inputs other than the tariff change equal to their benchmark values in Version 1, Table 3.[4] The table reports effects for additional tariffs on U.S. import from China of 2%, 4%, 6%, 8%, or 10%. (The 5% additional tariff in the benchmark simulation falls within this range.) Larger tariff increases result in larger reductions in the quantity of U.S. imports from China and in larger increases in the U.S. consumer price index for the industry.

Table 4: Simulations Using the Single Market Model

Additional Tariff	2%	4%	6%	8%	10%
Estimates (in % Changes)					
$\hat{q}_{ch,us}$	-9.36	-18.72	-28.08	-37.44	-46.80
$\hat{I}_{us}$	0.52	1.05	1.57	2.10	2.62

If it were necessary to re-calibrate the single market model to simulate each different tariff change, then there would be no benefit to using a single market model rather than using a global model for all of the simulations. Instead, we can use the same abbreviated single market model to estimate the economic effects for any tariff change $\hat{\tau}_{ch,us}$ as long as θ_{jk} is set to $R_{j,k}$. On the other hand, if the θ_{jk} values are based on ad hoc guesses, the estimated quantity and price effects will not be consistent with the underlying global model. For example, with the domestic supply elasticity value set to 1.5 and the import supply elasticity values set to 10, the single market model will generate quite different effects of

[4]When we run the single country model with a 5% or 10% additional tariff, it matches the price and quantity effects in Versions 1 and 4 in Table 2.

prices, quantities, and revenues. This comparison is illustrated in Table 5.

Table 5: Single Market Model with Different Supply Elasticities

Model Runs	Benchmark Calibrated Values	All Supply Elasticity Values are Positive
Inputs		
σ	8.1	8.1
β	0.593	0.593
$\hat{\tau}_{ch,us}$	0.045	0.045
Estimates (in % Changes)		
$\hat{p}_{us,us}$	0.97	0.80
$\hat{p}_{ch,us}$	-0.51	-1.61
$\hat{p}_{jk,us}$	0.06	0.42
$\hat{p}_{eu,us}$	0.02	0.42
$\hat{p}_{rw,us}$	0.36	0.42
$\hat{I}_{us}$	1.31	1.08
$\hat{q}_{us,us}$	1.42	1.17
$\hat{q}_{ch,us}$	-23.40	-16.11
$\hat{q}_{jk,us}$	8.81	4.23
$\hat{q}_{eu,us}$	9.13	4.23
$\hat{q}_{rw,us}$	6.40	4.23
$R_{us,us}$	1.5	1.5
$R_{ch,us}$	46.3	10.0
$R_{jk,us}$	139.9	10.0
$R_{eu,us}$	404.1	10.0
$R_{rw,us}$	17.8	10.0

5 Examples from Other Manufacturing Industries

Finally, we apply the global model to other manufacturing industries. Again, we use WIOD data on bilateral shipment values in 2014, aggregate the countries into the same five country-regions, and estimate the effects of a hypothetical additional 5% tariff on U.S. imports from

China. For each of the simulations, we use an industry-specific estimate of the elasticity of substitution from Hertel et al. (2007) and an industry-specific estimate of the cost share of variable factors from the 2017 Economic Census. We adopt the benchmark assumption that there is one supply chain for domestic shipments and a separate one for exports.

Table 6 reports the share of China's exports in each industry that are shipped to the United States ($\mu_{ch,us}$), the elasticity of substitution (σ), and the ratios of quantity and price changes for a dozen manufacturing industries, including the electrical equipment industry analyzed in Section 4. The estimate of $R_{ch,us}$ is inversely related to $\mu_{ch,us}$, with a correlation of -0.826 across the industries in Table 6. The ratio is larger the smaller is the importer as a share of the exporter's global shipments *within the specific industry.*

Table 6: Estimated Elasticity Values for Each Manufacturing Industry

Manufacturing Industry	$\mu_{ch,us}$	σ	β	$R_{us,us}$	$R_{ch,us}$	$R_{jk,us}$	$R_{eu,us}$
Food, Beverages, and Tobacco	0.096	4.0	0.640	1.8	55.0	614.3	-514.8
Textiles, Apparel, and Leather	0.179	7.5	0.660	1.9	38.1	412.8	-8692.5
Wood Products	0.140	6.8	0.678	2.1	53.8	-269.8	-83.3
Paper Products	0.235	5.9	0.627	1.7	25.6	193.6	-115.0
Printing	0.048	5.9	0.563	1.3	138.3	-92.7	-29.3
Chemical Products	0.166	6.6	0.514	1.1	37.2	214.5	214.7
Rubber and Plastic Products	0.158	6.6	0.612	1.6	41.2	-289.8	-116.8
Non-Metallic Mineral Products	0.115	5.8	0.551	1.2	50.8	96.0	106.2
Electrical Equipment	0.145	8.1	0.593	1.5	46.3	139.9	404.1
Machinery	0.158	8.1	0.596	1.5	45.9	122.2	734.2
Transport Equipment	0.151	8.6	0.692	2.2	60.2	103.8	698.6
Furniture and Other Manufacturing	0.258	7.5	0.510	1.1	21.6	247.7	-316.5

6 Conclusions

Single market models can be practical tools for quantifying the economic impact of tariff changes. However, it can be challenging to determine the magnitude of key parameters of the models, since they are difficult to directly measure. We have demonstrated how supply elasticity values can be calibrated to data on international shipment and cost shares and then used in an abbreviated single market model to simulate the effects of tariff changes.

The bottom line is that it is preferable to estimate the economic effects of a tariff change using a global model of the industry, but an abbreviated single market model can still be a practical, convenient, and even accurate tool if the appropriate supply elasticity values are used. These values should not be based on ad hoc guesses. They should generally reflect the pattern of international shipment shares and the specificity of supply chains in the industry even if it is not feasible to build a full global model of the industry.

There are other advantages of global models that cannot be replicated by an appropriately calibrated single market model. Global models can estimate the effects of the tariff changes on consumer prices, imports, and domestic production in the other countries and the effects of changes in the policies of the other countries (like reciprocal tariff reductions or retaliatory tariff increases), while single market models cannot.

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